Mutual Exclusivity in Autism Spectrum Disorders: Testing the Pragmatic Hypothesis

Running head: MUTUAL EXCLUSIVITY IN AUTISM

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Ashley de Marchena

University of Connecticut, Storrs

Inge-Marie Eigsti

University of Connecticut, Storrs

Amanda Worek

Harvard University

Kim Emiko Ono

Harvard University

Jesse Snedeker

Harvard University

Abstract

While there is ample evidence that children treat words as mutually exclusive, the cognitive basis of this bias is widely debated. We focus on the distinction between pragmatic and lexical constraints accounts. High-functioning children with autism spectrum disorders (ASD) offer a unique perspective on this debate, as they acquire substantial vocabularies despite impoverished social-pragmatic skills. We tested children and adolescents with ASD in a paradigm examining mutual exclusivity for words and facts. Words were interpreted contrastively more often than facts. Word performance was associated with vocabulary size; fact performance was associated with social-communication skills. Thus mutual exclusivity does not appear to be driven by pragmatics, suggesting that it is either a lexical constraint or a reflection of domain-general learning processes.

Key Words: mutual exclusivity; word learning; autism; pragmatics; Asperger's syndrome

In *Categorization and Naming in Children* (1989), Ellen Markman presented a set of questions and phenomena that have fueled research on word learning for twenty years. Early cognitive accounts of language acquisition focused primarily on syntax (see the papers in Slobin, 1985 for examples and Clark, 1973 for a discussion), perhaps because many theorists assumed that word learning could be explained by simple associations between word forms and referents. This assumption was challenged by researchers who pointed out that the midcentury philosophical critiques of empiricism (Quine, 1960; Goodman, 1966) were transparently applicable to the problem of lexical acquisition; that is, the input itself can never logically disambiguate the meaning of a word (see e.g., Macnamara, 1982; Markman & Hutchinson, 1984, Landau, Smith & Jones, 1988). The experiments that followed demonstrated that young children do not learn words through brute force associative learning; instead they approach the task with a set of constraints that help guide them to the correct meaning, minimizing the need for extensive observation. For example, children preferentially map labels to whole objects, rather than their parts or other qualities, and they extend these labels to other members of the same taxonomic category, rather than to thematically-associated objects (Markman & Hutchinson, 1984; Markman, 1990). In the case of novel artifacts, these taxonomic categories are typically inferred on the basis of the object's shape or function, rather than its color, texture, or location (Landau, Smith, & Jones, 1988; Kemler Nelson, Frankenfield, Morris & Blaire, 2000).

The discovery of these constraints on word learning immediately raised questions about their origins and their scope. Are these particular constraints present at the onset of word learning or do they emerge as the product of prior word learning (see e.g., Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002)? Are these constraints specific to word learning

or are they side effects of more general constraints on conceptualization or communication (see e.g., Bloom, 2000; Clark 1990)? This paper focuses on two theories about the scope and origins of a constraint that Markman dubbed "mutual exclusivity" (Markman & Wachtel, 1988).

Mutual exclusivity, in Markman's theory, is the learner's bias to assume that category labels apply to mutually exclusive sets of objects and thus each object has only one category label. This bias is evidenced by children's tendency to avoid a second label for a single referent. For example, imagine a child sitting in the kitchen with her mother. Two objects previously unknown to the child, a pepper and a bok choy, are in front of her on the counter. The mother holds the pepper up to her child and states, "What a pretty pepper!" Given the social cues available in this context, the child will presumably link this label, correctly, to the pepper. Imagine next that the mother puts the pepper back down on the counter and says, "Bok choy is delicious!" while glancing in the general direction of both vegetables. Mutual exclusivity, and experiments that support it, suggest that the child will be able to infer that the new label ("bok choy") applies to the unlabeled object (the bok choy), despite the ambiguous social cues that accompany this utterance.

Mutual exclusivity is a robust phenomenon. It has been observed in a variety of experimental paradigms, in children as young as 12 months of age (Clark, 1988; Diesendruck & Markson, 2001; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Graham, Poulin-Dubois, & Baker, 1998; Halberda, 2003, 2006; Littschwager & Markman, 1994; Markman, Wasow, & Hansen, 2003; Scofield & Behrend, 2007; Xu, Cote, & Baker, 2005). The phenomenon is present in diverse populations, including bilingual children (Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005), deaf and hard-of-hearing children (Lederberg, Prezbindowski, & Spencer, 2000), children with William's Syndrome (Stevens & Karmiloff-Smith, 1997), and

children with autism (Preissler & Carey, 2005). But while there is ample evidence that children treat words as mutually exclusive, the cognitive basis of this bias is widely debated (Bloom, 2000; Clark, 1990; Diesendruck & Markson, 2001; Markman et al., 2003; Merriman & Bowman, 1989; Mervis, Golinkoff & Bertram, 1994).

Two types of paradigms have been used to demonstrate mutual exclusivity. These subtly different paradigms support very different inferences about the nature of the constraint.

Novelty paradigms (Graham et al., 1998; Halberda, 2003; Markman & Wachtel, 1988; Preissler & Carey, 2005) present participants with one familiar object (e.g., a ball) and one novel object, and then ask them to produce an object based on a novel label (e.g., "give me the wug"). Participants typically select the novel object in this context. Although critical to the early observations of mutual exclusivity, novelty paradigms are limited in that they confound novelty with exclusivity. That is, the only novel object is also the only unlabeled object, so when children select the novel object, we cannot be certain that they are selecting this object because it is unlabeled (and thus treating words exclusively), or on the basis of its novelty alone, perhaps reflecting a simple preference for novel objects, or a tendency to match novelty to novelty.

Exclusivity paradigms (Diesendruck & Markson, 2001; Scofield & Behrend, 2007; Xu et al., 2005) remove the novelty confound by presenting children with *two* novel objects, labeling one with a novel label (e.g., "this is a jop"), and then asking for an object using a second novel label (e.g., "give me the wug"). Since both objects are novel, the possibility that children are solving this task by simply matching novelty to novelty can be ruled out, and we can conclude that children are selecting the novel object because it is unlabeled. Exclusivity paradigms thus provide clear evidence that the child is making the inference that novel words go with unlabeled objects.

Several theories have been put forward to explain the robust mutual exclusivity bias; the two theories that are most relevant for the present experiment are the pragmatic account and the lexical constraints account. The *pragmatic account* proposes that mutual exclusivity is just one manifestation of broader social communicative competence (Clark, 1990; Bloom, 2000; Diesendruck & Markson, 2001; Markman & Woodward, 1998). Infants are able to make inferences about adults' intentions including their communicative or referential intentions (Akhtar, Carpenter, & Tomasello, 1996; Carpenter, Akhtar, & Tomasello, 1998; Olineck & Poulin-Dubois, 2005; Woodward, 1998). According to the pragmatic hypothesis, this ability to infer referential intentions is the basis of exclusivity effects. For example, Clark (1987, 1990) proposes that listeners (infants and adults) are guided by the principle of contrast, which posits that different linguistic forms arise from different communicative intentions. Specifically in the case of referential terms (noun phrases or descriptions), listeners assume that different forms must pick out different referents. This can be seen as an implicature arising from the Gricean maxim of manner which states that speakers will state things in the simplest and least ambiguous manner possible (1957). If an object already has a mutually known label, failure to use this label implies that the speaker must not intend to refer to that object. To extend the earlier example, on the pragmatic hypothesis, the child who hears "bok choy" (unconsciously) reasons as follows: "if mom had wanted to refer to that object [the pepper] she would have used the same description as before ('pepper'), but she used a different description, so she must be referring to something else and this [the bok choy] is the only likely candidate."

In contrast to the pragmatic account, the *lexical constraints account* proposes that early in word learning, children assume that words (or at least object labels) refer to mutually exclusive categories, such that individual objects are assigned one, and only one, object label (Markman &

Wachtel, 1988). Based on this assumption, children reject objects with known names as possible referents for novel words, whittling down the number of possible referents. When an unlabeled object is present during a labeling act with a novel word, then the whole object constraint (Markman, 1990) will lead children to assume that the novel label applies to this object. On this hypothesis, both constraints are domain-specific mechanisms specific to word learning (Markman, 1992; see also Merriman & Bowman, 1989, Golinkoff et al. 1994). In our earlier example, a child using the mutual exclusivity constraint would (unconsciously) reason as follows: "That object [the pepper] is called a 'pepper', so it can't be called 'bok choy.' But this object [the bok choy] doesn't have another name, so it must be the bok choy."

A third type of theory, the domain-general account, attributes the phenomenon of mutual exclusivity to domain-general learning processes. On domain-general accounts, word learning constraints are either a direct reflection of the structure of domain-general learning mechanisms or are the result of applying these learning mechanisms to input which has underlying structure that gives rise to the relevant constraint (Smith et al., 2002; Regier, 2005).[1] For example, Regier (2003) proposes that mutual exclusivity arises from general mechanisms of competition in a connectionist network. As a word becomes more associated with one referent the probability that the same word will be used with another referent declines sharply. Similarly, Frank and colleagues (2009) were able to simulate mutual exclusivity effects in a Bayesian model of word learning and intention reading which contained no initial structure or parameters that were

[1] Constraints were initially motivated by the need to limit the possible hypotheses that the child considered to avoid the logical problem of induction (Quine, 1960; Goodman, 1966). Consequently, theories that posit that constraints are learned via association would seem to risk circularity. In practice they avoid it by positing that word meanings are drawn from a finite hypothesis space. In other words, the initial, strong constraints in such models are built into the input representation.

specifically linguistic in nature. These domain-general models present a compelling challenge for the lexical constraints account, which we explore further in the discussion section. However, for now we put the domain-general theory aside, as the current study was designed to distinguish between pragmatic and lexical constraints accounts.

The pragmatic account and the lexical constraints account differ in their scope: although lexical constraints apply only to words, the ability to infer speakers' referential intent should apply to all speech acts, including descriptions of objects. Studies of conversational communication have demonstrated that speakers typically settle on a single form for a given referent and then use it throughout their discourse. Initially these descriptions may be long and variable, but they become shorter and more predictable as interlocutors settle on a common referential understanding (Krauss & Weinheimer, 1966). Thus listeners expect speakers to refer to the same object consistently, because this is what they typically do.

Diesendruck and Markson (2001) tested the prediction that exclusivity applies to diverse speech acts by comparing children's tendency to treat words contrastively with their tendency to treat facts contrastively. A standard exclusivity task was used to test exclusivity for words (label condition) and a parallel task was constructed to test exclusivity for facts (fact condition). Specifically, one of the two novel objects was linked to a novel *fact* ("my sister gave me this") and children were then asked to produce the referent of a second novel fact ("Can you give me the one my dog likes to play with?"). Diesendruck and Markson reasoned that if mutual exclusivity was subserved by a lexical constraint, then children should treat words as exclusive, but not facts. In contrast, if mutual exclusivity was the result of a broader social pragmatic constraint, then both words and facts should be treated as exclusive. They found that three-year-olds performed similarly in the label and fact conditions, treating both forms as exclusive. Thus

they concluded that the same social pragmatic inference accounted for performance in both conditions. This is spelled out as Hypothesis A, below. But note that these results are logically compatible with the possibility that exclusivity for words and facts are subserved by different mechanisms that just happen to be equally robust in three-year-old children. This is spelled out as Hypothesis B.

> Hypothesis A (Diesendruck & Markson, 2001): A single factor, social pragmatics, underlies children's tendencies to treat words and facts contrastively. This tendency is driven by children's expectation that speakers will refer to a single object consistently. This expectation alone accounts for the mutual exclusivity bias.
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> Hypothesis B: Different mechanisms account for exclusivity in words and facts. The tendency to treat words as mutually exclusive is the result of lexical constraint, and thus specific to word learning. However, children also have access to social pragmatic reasoning processes that may lead them to treat facts contrastively as well.

In the absence of further data, Hypothesis A should be favored on the basis of parsimony. Why posit two mechanisms when one will do? However, given the pervasiveness of exclusivity for words, it is critical to determine whether exclusivity for facts is present in the same range of tasks and populations. Any lack of parallelism in the development or prevalence of exclusivity for words and other speech acts would favor Hypothesis B.

Preliminary support for Hypothesis B comes from research on mutual exclusivity at earlier stages of development. Scofield and Behrend (2007) found that two-year-olds treat words as exclusive but not facts, suggesting that separate mechanisms may underlie performance in the two conditions (see also Markson, 2005). This data, however, is difficult to interpret due to the young age of the participants. To use the principle of contrast, the child must recognize that the

speaker is producing two different referential forms. In the case of the words this simply involves representing the phonological forms of the two labels and comparing them ("zav" is not "koba"). In contrast, the facts are phrases that are longer in length and have internal syntactic and semantic structure. Furthermore in this task the syntactic form of the facts shifts from the exposure phrase in which a declarative form is used ("My uncle gave me this") to the test phase, in which a definite description is produced ("The one my cat stepped on"). Very young children, with limited linguistic abilities, may have difficulty representing these facts, holding them in memory, or comparing them to determine whether a contrasting form was used (Markson, 2005). Even if they succeed at all of these tasks, they may have fewer resources left for making inferences about the experimenter's referential intent. Thus, for two-year-olds, performance on the label condition may be superior to performance on the fact condition simply because the labels are simpler. Thus additional work is needed to understand whether the contrastive interpretation of words and the contrastive interpretation of facts are driven by the same cognitive mechanisms as the pragmatic account proposes.

To tease apart Hypotheses A and B, above, we have chosen to look at mutual exclusivity in a group of children and adolescents who show impoverished social pragmatic reasoning, specifically individuals with autism spectrum disorders (ASD). ASD is a neurodevelopmental disorder characterized by profound deficits in social interaction and communication, and by repetitive and restricted behaviors and interests (APA, 2000). Individuals with ASD are notably impaired in their ability to infer speakers' referential intent (Baron-Cohen, Leslie, & Frith, 1986; Phillips, Baron-Cohen, & Rutter, 1998; Sabbagh, 1999). Within the ASD population, there is great heterogeneity in terms of linguistic abilities; many never go on to develop fluent speech, while others demonstrate superior verbal skills (Kjelgaard & Tager-Flusberg, 2001; Tager-

Flusberg, 2006). However, even for those who develop average and above average language skills, pragmatic abilities are universally impaired (Tager-Flusberg, Paul, & Lord, 2005). In contrast, vocabulary development tends to be an area of relative strength (Jarrold, Boucher, & Russell, 1997; Kjelgaard & Tager-Flusberg, 2001). Although most linguistic and communicative skills for individuals with ASD (such as conversational discourse and nonverbal communication) tend to fall below what would be expected given their overall cognitive levels, vocabulary size is often commensurate with overall cognitive capacities. The fact that many children with ASD are able to build substantial vocabularies despite impoverished social pragmatic skills provides a preliminary suggestion that pragmatic skills may not be a necessary condition for word learning and vocabulary development. With respect to mutual exclusivity this suggests two possibilities: (1) mutual exclusivity is a pragmatic skill but highly verbal children with ASD are able to use other cues and strategies to compensate for the absence of mutual exclusivity (consistent with the pragmatic hypothesis) or (2) mutual exclusivity is fully present in verbal children with ASD suggesting that it does not depend on the kind of pragmatic skills that are impaired in this population (consistent with a lexical constraints hypothesis).

Because children with ASD show such profound deficits in social interaction, studies of word learning in ASD have primarily focused on how these children's social deficits interfere with their word learning. Children with ASD are notably impaired in their ability to initiate and follow joint attention, a deficit associated with extensive delays in early language acquisition (Bono, Daley, & Sigman, 2004; Loveland & Landry, 1986; Mundy, Sigman, & Kasari, 1990). The abilities of children with ASD to follow a speaker's direction of gaze (Baron-Cohen, Baldwin, & Crowson, 1997) and focus of attention (McDuffie, Yoder, & Stone, 2006) have been shown to be significantly related to their ability to correctly apply novel labels to novel objects.

The ability to interpret speakers' referential cues appears to be more of a rate-limiting step to word learning for children with ASD than for children with typical development (TD), presumably because their deficits in this area present roadblocks for acquisition (Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007). Despite these limitations, the majority of children with ASD (> 80%) are able to learn words, particularly nouns, by middle childhood (Lord, Risi, & Pickles, 2004). In fact, children with ASD have been shown to apply some of the same constraints that TD children do, such as interpreting novel words as referring to objects rather than actions (Swensen, Kelley, Fein, & Naigles, 2007).

To our knowledge, only one published study has examined the mutual exclusivity bias in children with ASD. Preissler and Carey (2005) studied mutual exclusivity in 20 five- to nine-year-old children with autism. Their sample had a mean receptive vocabulary age equivalent of 23 months. These children were impaired in their ability to use speakers' direction of gaze as a strategy for making word-object mappings, suggesting that they did not use speakers' referential intent to guide word learning. The same group of children, however, successfully completed a *novelty* task; that is, when presented with a familiar object and an unfamiliar object and asked to show the experimenter a "blicket," they reliably chose the unfamiliar object. The low verbal level of the participants likely motivated the simpler paradigm that was used in this study. The novelty task consisted of only two trials: one trial included a familiar drawing and a novel drawing as stimuli, the second trial used a familiar object and a novel object. The familiar things were always natural kinds (apple and duck) and the novel things were complex artifacts (airpump and noisemaker). Despite their impairment in using eye gaze to infer referential intent, the children systematically paired the novel words with the novel referents. However, this study was limited by the presence of a novelty confound. We cannot be certain that the phenomenon they

observed is really about *exclusivity*. That is, the children in their study could simply have been matching novelty to novelty, or showing a preference for novel, mechanical objects if the task was unclear, a possibility that is even more likely for children with ASD, who often show a distinct preference for mechanical objects (South, Ozonoff, & McMahon, 2005). To conclude that children are truly using an exclusivity strategy, an exclusivity paradigm must be used.

In the current study, we use Diesendruck and Markson's (2001) exclusivity paradigm to compare children's exclusivity for words with their exclusivity for facts. Our goal was to answer three questions. First, are individuals with ASD truly using exclusivity in word learning despite their pragmatic impairments? If so, this suggests that the cognitive basis of exclusivity is not tightly tied to social pragmatic skills. Second, do individuals with ASD apply exclusivity to other referential acts, such as factual descriptions? This provides an index of children's ability to use contrasting forms to make inferences about the referential intent of others. Third, what are the correlates of using exclusivity for words and for facts? Individuals with ASD provide advantages for studying typical developmental processes such as word learning (Cicchetti & Rogosch, 1996; Marcus & Rabagliati, 2006), in part because they introduce more variability, within and across domains, than is found in typical populations. We take advantage of this variability to explore additional predictions of pragmatic and lexical constraints accounts.

In contrast to Preissler and Carey (2005), we limited our sample to participants who had average or above average language abilities for their age. As we noted earlier, comprehension of the facts may be taxing for children with limited linguistic abilities, thus we wanted to ensure that participants in this study had verbal skills that were at least as well developed as the three- to four-year-old children who succeed in this task (Diesendruck & Markson, 2001; Scofield & Behrend, 2007). In addition, the exclusivity task itself is demanding, involving two novel

linguistic forms and two novel objects, thus lower functioning children might fail for uninteresting reasons.

We compared our participants with ASD to TD controls who were matched on age and vocabulary ability. Two different age groups were tested (children and adolescents) to explore whether exclusivity for words and facts changes over development. Previous studies have demonstrated that word learning strategies change over development (Halberda, under review; Merriman & Bowman, 1989; Nazzi & Bertoncini, 2003), but this work has focused on development in the first four years of life. On the pragmatic hypothesis, exclusivity for words and facts should remain yoked across the lifespan. Finally, for a subset of the participants we conducted a control task to assess memory and attention for novel words and facts. Even high-functioning individuals with ASD often have deficits in attention (Landry & Bryson, 2004; Townsend, Harris, & Courchesne, 1996) and memory (Bennetto, Pennington, & Rogers, 1996; Williams et al., 2005). The control task allowed us to disentangle the role of these factors in any group differences that emerge.

A pragmatic account and a lexical constraints account predict different patterns of findings from the current study. Critically, a pragmatic account attributes performance on the fact and label conditions to a single, underlying factor: the ability to infer speakers' referential intent. The pragmatic account thus predicts that both diagnostic groups should treat words and facts as mutually exclusive to an equivalent degree. With respect to group differences, the pragmatic account predicts that the TD group should perform better than the pragmatically-impaired ASD group on both conditions, since they each rely on the ability to infer referential intent. In addition, because exclusivity for facts and exclusivity for words are produced by the same cognitive mechanism, then any individual characteristics that are related to one should be

related to the other. A lexical constraints account, on the other hand, attributes performance on the two conditions to very different factors: the mutual exclusivity constraint in the label condition, and some other process, perhaps social pragmatic reasoning, in the fact condition. Thus there is no reason to expect the tasks to pattern together in either population. On the lexical constraints hypothesis there is also no reason to expect that participants in the ASD will be impaired on the label condition, since the lexical constraint that it taps is independent of social pragmatic skills and the children and adolescents that we are testing do not have intellectual or lexical impairments. While this hypothesis does not make any specific predictions with regard to the fact condition, it leaves open the possibility that performance in this task is driven by social pragmatic skill and will be impaired in ASD. Finally, since performance on the two conditions is thought to be driven by distinct mechanisms, a lexical constraints account does not predict that individual differences associated with one condition are necessarily associated with the other. That is, different factors may be associated with performance in the fact and label conditions.

Method

Participants

Children and adolescents with ASD. Participants were 30 children and 18 adolescents with high functioning ASD, recruited from special needs schools in New England, through community groups serving parents of children with special needs, and by word of mouth. Participants were initially selected based on a parent's report that the child both had an ASD (Autistic Disorder, PDD-NOS, or Asperger's Disorder) and had language abilities that were approximately at chronological age level.

Parents of all participants completed the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), a screener for symptoms of ASD. For the younger age group,

ASD diagnoses were confirmed through the review of clinical diagnostic reports provided by the parents when these were available. When diagnostic reports were not available children were required to meet criteria for an ASD diagnosis on the SCQ. One participant failed to do so and was excluded. For the older age group, diagnoses were confirmed through the administration of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002), Module 3 or 4, by a trained clinician (AdM). One participant was excluded for failure to meet criteria for an ASD diagnosis on the ADOS.

Receptive vocabulary was assessed with the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997). Participants were included who had PPVT scores of 85 or above. Four participants with ASD were excluded for scoring below this cutoff. Thus the final ASD sample consisted of 26 children and 16 adolescents. Participant details are given in Table 1.

Typically developing children and adolescents. The ASD sample was compared to a sample of TD children and adolescents who were matched on chronological age and receptive vocabulary. Participants were 52 children and 16 adolescents with a typical developmental history, including no first-degree relatives with an ASD diagnosis, no developmental delays, and no known neurological impairments. Participants were recruited through their schools and via word of mouth. 28 participants were excluded for the following reasons: failure to match to the ASD group (n = 20), high score (above nine) on the SCQ (n = 4), experimenter error in task administration (n = 3), and for current concerns regarding social impairments (n = 1). The final TD group consisted of 24 children and 16 adolescents.

Standardized Measures

The PPVT (Dunn & Dunn, 1997) is a widely used measure of receptive vocabulary from preschool age to adulthood. Participants are presented with four pictures of objects, actions, and

events from which they must select the appropriate referent of a word stated by the experimenter. The reliability and validity of this measure are well established.

The SCQ (Rutter et al., 2003) is a 40-item parent questionnaire for the screening of ASD symptoms in children. Items on the measure were derived from the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994), which is considered to be a highly valid measure for diagnosing ASD. When used as a screening instrument, a cutoff score of 15 is recommended as an indication of a possible ASD (Rutter et al., 2003).

The ADOS (Lord et al., 2002) is a semi-structured assessment for the diagnosis of ASD, which provides multiple opportunities for social and communicative engagement. The reliability and validity of this measure are well established. Depending on their age and maturity level, participants in this study were administered either Module 3 or Module 4, which are both intended for individuals with fluent speech. The ADOS was administered to adolescent participants only.

Task Design

The experimental task was based on Diesendruck and Markson (2001, Study 1). This task employs a standard exclusivity paradigm for words: participants are shown two novel objects, one of which is given a novel label, then they are asked to choose an object using a second novel label. The same paradigm is also given using facts instead of labels (i.e., rather than labeling and requesting an object with a novel word, an object is described using a novel fact and requested using a second novel fact). These two conditions, hereafter the *label* and *fact* conditions, respectively, were administered within subjects with the order counterbalanced across participants.

A subgroup of participants also received a control task, which was identical to the exclusivity task, except that an object was requested using the same novel label or fact that was given to the first object. This control task was always given after both experimental conditions were completed.

Stimuli

Twenty-four pairs of novel objects were used in this study. Novel objects consisted of unusual household items (e.g., a tea egg, a yellow plastic drain catcher) or novel artifacts created in the lab (e.g., a plastic lid glued to a wooden craft stick). Each item was distinct in appearance and most participants found them to be both interesting and unfamiliar.

Novel Labels and Facts

All novel words were single CVC syllables conforming to the rules of English phonology (e.g., "wug" and "jop"). Novel facts were statements such as "This one is from California" or "This is the one my sister gave me." The twelve novel words and the twelve facts used in the exclusivity task can be found in Diesendruck and Markson (2001; Study 1).

Procedure: Exclusivity Task

Label condition. In the training phase of each trial, the experimenter placed a pair of novel objects in front of the participant, one on either side of the table. The experimenter then picked up Object A and engaged the participant in joint attention by alternating her gaze between the child and the object, and looking at the object with fascination. Because attentional impairments in ASD have been noted to interfere with word learning (Baron-Cohen et al., 1997), care was taken to ensure that the child or adolescent's attention was on the object before proceeding. Despite their limitations, children with ASD orient to objects attended to by others when the cues are salient enough (Bayliss & Tipper, 2005). Once the participant was looking at

the object, the experimenter looked at it and labeled it three times, saying, "Here's the *jop*. Look this is a *jop*. See the *jop*?" The experimenter then placed Object A back on the table, and picked up Object B. After the participant's attention was on Object B, the experimenter looked at the object and said, "Oh look at this one. Isn't it cool? This is nice." The experimenter then placed Object B back on the table and allowed the participant to explore both objects for approximately 30 seconds.

After this the experimenter proceeded to the question phase. The experimenter picked up both objects and placed them in their original locations. While looking at the participant (and not at either of the objects) the experimenter asked the participant for the referent of a second novel label, for example, "Can you give me the *wug*?" The experimenter provided no further information, but encouraged the participant to make a selection (e.g., if the participant was reluctant to make a choice, the experimenter stated, "just take your best guess"). After making a choice, the participant was thanked for providing one of the objects, but no explicit feedback was given. This procedure was repeated for six trials. The labeled object (i.e., Object A or Object B) alternated across trials.

Fact condition: The procedure in the fact condition was the same as the label condition, with two exceptions. First, rather than labeling one of the objects with a novel word in the training phase, the experimenter provided a brief factual description, for example, "Look at this one, *my sister gave this to me*. See, *my sister gave this to me*. *My sister gave me this*." Second, during the question phase, the experimenter asked the participant for the referent of a different fact, for example, "Can you give me *the one my dog likes to play with*?"

The specific stimuli used for each condition, the side of presentation of these stimuli, and the order in which the label and fact conditions were presented were fully counterbalanced across

participants. To minimize the chance that participants would directly apply strategies that they had formed in the first condition to the second condition, the second condition was administered no sooner than two weeks after the first, with the exception of two adolescents with ASD who were given the second session after a delay of several hours.

Procedure: Memory Control Task

Twenty-seven participants with ASD and 24 participants with TD also completed a memory control task to test for differences in attention and memory that could affect performance on the experimental task. The procedure for the control task consisted of the same training phase as the mutual exclusivity task. In the question phase, however, the participant was queried using the *same* label or fact that was used in the training phase. For example, the experimenter would describe Object A as follows: "Here's the jop. Look, this is a jop. See the jop?" and in the question phase, would ask, "Can you give me the jop?" This task was always administered subsequent to both the experimental label and fact conditions.

All children were tested in a quiet room that was free from distractions. Testing took place in the participant's home or school or in our laboratories at Harvard University or the University of Connecticut. On the first day of testing, participants completed the PPVT, ADOS (adolescent participants only), and the first condition (either label or fact) of the exclusivity task. Parents were also given the SCQ to complete. ASD participants who met inclusion criteria and TD participants who met inclusion criteria and were appropriately matched to the ASD group were invited back for a second day of testing, during which they completed the second condition of the mutual exclusivity task, and (for 51 participants) both conditions of the memory control task. In all cases, the experimenter was the same for both days of testing. Participants were

always seated across a table from the experimenter. A digital camera was positioned behind the experimenter to videotape participant responses.

Results

Dependent variables were examined for deviations from the assumptions of normality and sphericity and were found to be normally distributed. We found no significant differences between our two age groups, therefore all data are presented collapsed across age group.

Task Performance: Exclusivity Task

A two-way repeated measures ANOVA with diagnostic group and condition as independent variables and task success (i.e., the proportion of unlabeled object choices) as the dependent variable revealed a significant main effect of condition, $F(1, 80) = 15.30$, $p < .001$, partial $\eta^2 = 0.16$. The main of effect of diagnostic group was nonsignificant, $F(1, 80) = 1.20$, $p = .28$, partial $\eta^2 = 0.02$, as was the group by condition interaction, $F(1, 80) = 0.43$, $p = .51$, partial $\eta^2 = 0.01$. These findings suggest that participants with ASD and participants with TD performed similarly on both conditions. Post hoc t-tests revealed that labels were treated as mutually exclusive more reliably than facts by both the ASD group $t\ (41) = 3.40$, $p = .002$, Cohen's $d = 0.77$, and the TD group, $t\ (39) = 2.22$, $p = .03$, Cohen's $d = 0.53$ (Figure 1). This discrepancy suggests that different mechanisms underlie performance on the fact and label conditions. Although participants were more likely to choose the unlabeled object in the label condition than in the fact condition, performance for both groups was above chance on both conditions (ASD label, $t\ (41) = 31.70$, $p < .001$, Cohen's $d = 2.03$; ASD fact, $t\ (41) = 14.62$, $p < .001$, Cohen's $d = 0.58$; TD label, $t\ (39) = 23.22$, $p < .001$, Cohen's $d = 1.57$; TD fact, $t\ (39) = 17.86$, $p < .001$, Cohen's $d = 0.92$).

To investigate effects of order, separate two-way ANOVAs were performed on the label and fact conditions, with diagnostic group and condition order as independent variables, and task success as the dependent variable. For the label condition, there was no significant main effect of group, $F(1, 78) = 0.09$, $p = .77$, partial $\eta^2 = 0.001$, or order, $F(1, 78) = 0.42$, $p = .52$, partial $\eta^2 = 0.01$, and no group by order interaction, $F(1, 78) = 2.18$, $p = .14$, partial $\eta^2 = 0.03$. For the fact condition, there was no main effect of group, $F(1, 78) = 1.65$, $p = .20$, partial $\eta^2 = 0.02$, and no group by order interaction, $F(1, 78) = 1.93$, $p = .17$, partial $\eta^2 = 0.02$. However, for the fact condition only, the main effect of order was significant, $F(1, 78) = 12.91$, $p = .001$, partial $\eta^2 = 0.14$ (order effect presented in Table 2). Children and adolescents who received the label condition first (and, therefore, had experienced one version of the task) performed significantly better on the fact condition than children and adolescents who received the fact condition first and had no task experience. In other words, participants were more likely to treat facts as mutually exclusive once they had already done so with labels. In contrast, condition order had no effect on label performance; that is, prior experience with the fact task did not increase participants' tendency to treat labels as mutually exclusive. This order effect suggests that participants generalized from the label condition to the fact condition, but not from the fact condition to the label condition.

Individual Difference Analyses

At the group level, participants with ASD and participants with TD performed equally well on both the label and fact conditions. We were further interested in how individual differences in social pragmatic skill might relate to task performance. To explore these possible effects, we compared individual performance on the label and fact conditions to scores on a measure of socio-communicative impairment, the SCQ. Due to the non-parametric nature of the

task performance data, Spearman's rho was used for correlation analyses. Children and adolescents who treated facts as mutually exclusive more reliably were found to have lower SCQ communication scores (i.e., fewer behaviors associated with ASD communication symptoms); Spearman's rho (75) = -.29, p = .01. This finding supports the idea that the fact condition taps social pragmatic skills. In contrast, participants' SCQ communication scores were not correlated with performance on the label condition, Spearman's rho (75) = -.10, p = .41, suggesting that social pragmatic skills are unrelated to performance on the label condition.

If the tendency to succeed on an exclusivity task is truly related to vocabulary development, then we should expect that children and adolescents who are more successful on an exclusivity task will build larger vocabularies. To test this hypothesis, we compared our participants' performance on the label condition with their receptive vocabulary size, as assessed by the PPVT. PPVT standard scores were significantly positively correlated with performance on the label condition, Spearman's rho (82) = .40, $p < .001$, but not with performance on the fact condition, Spearman's rho (82) = .17, p = .13. Children and adolescents who consistently treat words as mutually exclusive have larger receptive vocabularies, whereas children who treat facts as mutually exclusive do not.

If the same form of reasoning underlies performance on both the label and the fact conditions, then successful performance on these two tasks should be correlated. In fact, label performance was uncorrelated with fact performance for the sample as a whole, Spearman's rho (82) = .04, p = .76, and within each diagnostic group (ASD: Spearman's rho (42) = .09, p = .59; TD: Spearman's rho (40) = -.07, p = .66). This finding further suggests that performance on the two conditions is supported by distinct mechanisms.

Task Performance: Memory Control Task

Twenty-seven participants with ASD and 24 participants with TD also completed a memory control task to test for the possibility of differences in attention and memory for the two conditions that may have affected performance. We found that memory for facts was significantly better than memory for labels, removing any concern that the facts were simply harder to process or retain. After comparing performance on the experimental task to performance on the control task, we found that participants were as successful on the experimental label condition as they were on the control label condition, t (50) = .242, p = .81, Cohen's d = 0.06. In contrast, participants performed significantly worse on the experimental fact condition than the control fact condition, t (50) = 5.25, p < .001, Cohen's d = 1.04, with a large effect size (Figure 2). The use of a mutual exclusivity strategy for labels was as efficient as explicitly being taught an object label. In contrast, using mutual exclusivity to identify the referent of a fact was significantly less reliable than simply being taught a fact about an object.

When we include only participants who achieved perfect performance on both the label and the fact control conditions (*N = 31)*, we continue to find that labels are treated as mutually exclusive more reliably than facts (label mean: 94% correct, fact mean: 75% correct; t (30) = 3.04, p = .005, Cohen's d = 0.77). After splitting perfect performers by diagnostic group, we found that, although both groups performed better on the label condition (ASD mean: 94% correct, TD mean: 94% correct) than on the fact condition (ASD mean: 61%, TD mean: 85% correct), this difference only reached significance in the ASD group, t (12) = 3.22, p = .007, Cohen's d = 1.14, and not in the TD group, t (17) = 1.27, p = .22, Cohen's d = 0.46.

Discussion

The current study was designed to contrast two competing hypotheses about the nature of the mutual exclusivity constraint in word learning. According to one account, the pragmatic

account, mutual exclusivity is one manifestation of a broader tendency to assume that speakers will use the same form for a given referent within a single discourse. The pragmatic account is consistent with Hypothesis A (see Introduction), that a single factor underlies performance on both label and fact conditions. In contrast, according to the lexical constraints account (consistent with Hypothesis B), mutual exclusivity is specific to word learning, and does not apply to other speech acts. On this account, distinct factors are proposed to underlie children's tendency to treat words and facts as mutually exclusive. In the present study, we found that children and adolescents with ASD and children and adolescents with TD showed mutual exclusivity for both words and facts; however, this tendency was far more reliable for words than for facts. The control task demonstrated that this relationship was not due simply to facts being harder to process or remember. Because our sample included children with variable pragmatic and linguistic skills, we were able to examine individual differences in performance. We found that performance on the label and fact conditions was uncorrelated and that the label and fact conditions were associated with different variables. Specifically, children with better social communication skills were more likely to treat facts as exclusive, suggesting that pragmatic skills underlie this ability. In contrast, children with larger vocabularies were more likely to treat words as exclusive, suggesting a connection to lexical skills. These findings strongly suggest that distinct mechanisms underlie performance on the label and fact conditions. Here we will review the implications of these findings for mutual exclusivity in ASD and the feasibility of the pragmatic hypothesis of mutual exclusivity, and then revisit the domain-specific lexical hypothesis and the domain-general hypothesis in light of these results.

Mutual Exclusivity in ASD

Children and adolescents with ASD offer a unique window into typical language acquisition processes. By studying the ways in which these remarkable individuals learn language despite their significant impairments in social interaction and nonverbal communication skills, we may gain additional leverage on the contribution of the different skills that children bring to the task of language acquisition. In addition to contributing to our understanding of typical language development, this paper offers insight into word learning processes for children with ASD. Specifically, we extend Preissler and Carey (2005) by demonstrating that individuals with ASD use mutual exclusivity to successfully determine the referents of novel words, in the absence of any confound between novelty and exclusivity.

One limitation of our study is that we included only children and adolescents with high-functioning ASD, thus the present findings may not generalize to more low-functioning children. Preissler and Carey's (2005) study demonstrates that even nonverbal children succeed in a novelty task, suggesting that, at the very least, a novelty preference for words is present in children at all points along the autism spectrum. This conclusion is supported by a recent study of word learning in children with ASD with substantial language impairments (Parish-Morris et al., 2007). In an experiment exploring the role of perceptual salience in word learning (Experiment 2), the authors included a probe with the essential features of an exclusivity task (two objects, one labeled directly, the other requested with a second label). The results suggested that these three- to seven-year-olds with ASD treated the second label as mutually exclusive.[2] In

[2] Because these authors were not specifically interested in mutual exclusivity, they did not present any statistical analyses to support the presence of this bias. However, the data that is reported suggests that mutual exclusivity is present in this population (Table 3, Parish-Morris et al., 2007).

sum, the current evidence suggests that, despite impairments in social pragmatics, individuals with ASD, across age and ability levels, use mutual exclusivity to learn words.

Nevertheless, there appear to be individual differences in the effectiveness with which children employ this strategy or the degree to which they adhere to it. Our finding that strong use of mutual exclusivity was related to vocabulary knowledge might predict a lower degree of adherence to mutual exclusivity in lower functioning children (with lower vocabulary levels). Consistent with this conjecture, adherence to exclusivity in the Parish-Morris (2007) study is substantially lower than in the present experiment (70% vs. 86%), though the methodological differences between the two experiments make this difference difficult to interpret. Additional research will be required to determine whether adherence to mutual exclusivity is a cause of greater vocabulary knowledge. The correlation could potentially reflect effects of variation in phonological processing and verbal working memory on both vocabulary acquisition and memory for the first novel word in this exclusivity task.

Testing the Pragmatic Hypothesis

The pragmatic account proposes that a single mechanism (e.g., the principle of contrast) underlies both the tendency to treat words contrastively and the tendency to treat facts contrastively. Thus it follows that performance on the label and fact conditions should be correlated, and that any individual differences that are associated with mutual exclusivity for words should also be associated with mutual exclusivity for facts. We found that the predictors of performance for the two conditions were different and that performance across the two conditions was uncorrelated, suggesting that distinct mechanisms drive mutual exclusivity for words and mutual exclusivity for facts.

Individual performance on the label condition was positively correlated with receptive vocabulary ability. This finding is consistent with previous work with infants that found a positive association between expressive vocabulary size and performance on a novelty task (Graham et al., 1998). These are important findings, because they confirm that the tendency to avoid lexical overlap may be critical to vocabulary development. In the present study, performance on the fact condition was not correlated with performance on the receptive vocabulary test. This finding is difficult to interpret within a pragmatic account of word learning, which proposes that vocabulary development is grounded in the same referential inference process that allows children to interpret facts as mutually exclusive in this task.

Although unrelated to vocabulary size, the fact condition was associated with ASD communication symptoms, such that children with better communication skills were more likely to treat facts as mutually exclusive. This finding supports the premise that the fact condition depends on children's pragmatic abilities, as Diesendruck and Markson (2001) suggest. In contrast, performance in the label condition was not associated with communication skills. Again, this is problematic for the pragmatic hypothesis, which proposes that the same pragmatic skills should underlie the contrastive interpretation of words. Taken together, individual difference measures suggest that the two conditions are associated with different factors: the label condition with vocabulary, and the fact condition with communication and social pragmatic skills. This pattern of differential correlation also suggests that the critical associations are not solely attributable to a common association with some domain-general factor (such as IQ), which would presumably influence performance in both conditions equally.

Our findings suggest that mutual exclusivity for words is more robust than mutual exclusivity for facts. Although both groups performed above chance in the fact condition,

performance was considerably lower than it was in the label condition. In fact, our data suggest that older children and adolescents are actually less likely to treat facts as contrastive than three-year-olds are. The first block of trials in our within subjects design is comparable to the between subjects design used in Diesendruck and Markson (2001); the tasks used similar stimuli and procedures, and the same labels and facts. The three-year-olds in that experiment succeeded on 82% of the label trials and 73% of the fact trials. Our TD sample of older children and teens showed similar performance for words (85%) but lower performance for facts (60%). Critically, the mean for facts performance in the Diesendruck and Markson study is not within the 95% confidence interval for our data, suggesting that three-year-olds are *more* likely to treat facts as mutually exclusive than older children and adolescents. This could reflect deeper processing of the facts by the older children. In both studies, the facts were paired so that they would not logically exclude one another (my sister gave it to me vs. I keep it under my bed). The older children in this study may have been more adept at determining when facts are incompatible, and thus may have realized that both facts could be used to refer to the same object. They may also be more accustomed to hearing a single object described in multiple ways, or be more able to think about an object in multiple ways (see e.g., Flavell, Flavell & Green, 1983).

The order effect observed in this study provides further support for the robustness of mutual exclusivity for words. Participants in our study showed an asymmetric pattern of generalization (Table 2). Those who received the label condition before the fact condition were far more likely to make the contrastive inference for facts, suggesting that they generalized a robust exclusivity strategy from words to facts. In contrast, participants who received the fact condition before the label condition performed no better on the label condition, suggesting that they were not able to generalize from the fact to the label condition. In fact, the ASD group

showed a marginal decline (p = .07) when the label task followed the fact task. This asymmetry suggests that participants initially bring very different strategies to the label versus the fact tasks. In the case of the label task, participants have a strategy available that supports a robust contrastive inference (e.g., a lexical constraint); this strategy is not available in the facts task. However, they seem to generalize from this lexical strategy when confronted with a parallel task involving novel facts (perhaps by thinking of the facts as names or labels). In contrast, participants who received the facts task first may not have had a stable and consistent strategy to apply. This was apparent in some of the older participants' reactions to the fact task – despite above chance performance, many stated that they were "just guessing."

The control task allowed us to look only at participants who were reliably able to remember novel labels and facts (i.e., those who were at ceiling on both control conditions). We found that the TD group was equally likely to treat labels and facts as mutually exclusive; the ASD group, however, treated labels as mutually exclusive more reliably than facts. Thus, when we remove some of the variability associated with faltering attention and memory, we find that the fact condition is sensitive to diagnostic status, unlike the label condition, further suggesting that performance on the label condition does *not* depend on social pragmatics.[3]

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[3] We do not wish to suggest that social pragmatics play no role in word learning. In fact, there is clear evidence that social *attentional* cues such as gaze direction (Baldwin et al., 1996) and joint attention (Woodward, Markman, & Fitzsimmons, 1994), and social *intentional* cues, such as discourse novelty (Tomasello & Akhtar, 1995) and the purposefulness of labeling acts (Diesendruck, Markson, Akhtar, & Reudor, 2004), contribute to word learning. Further, children's interpretations of speakers' communicative intentions may override their default assumptions (e.g., constraints) about word-object mappings, for example, in the presence of explicit instruction (Diesendruck, Markson, & Bloom, 2003) or unreliable speakers (Scofield & Behrend, 2008). What we wish to emphasize is that the ability to understand communicative intent does not appear to play a major role in the mutual exclusivity bias, which is intact in children and adolescents with ASD despite their significant impairments in pragmatics and social communication.

The Lexical Constraints Hypothesis for Mutual Exclusivity

Our finding that exclusivity is stronger for labels, or words, than it is for facts suggests that the former does not merely reflect the operation of a pragmatic principle of referential contrast. Any such principle would apply equally in both cases, predicting equivalent performance. Instead, mutual exclusivity for words must depend, at least in part, on another mechanism which supports a more robust contrastive inference. This is fully predicted by the hypothesis that mutual exclusivity is a domain-specific constraint that is limited to word learning, and perhaps some versions of the domain-general account (see below).

Specifically, the lexical constraints account predicts that in situations of referential ambiguity, lexical constraints will provide a strategy for disambiguation that is available only to words, and not to other speech acts. It follows that words should be treated as mutually exclusive more consistently than facts, which is precisely what the present data suggest. In fact, our control experiment demonstrated that, in the case of words, referential disambiguation via mutual exclusivity was as robust as referential disambiguation via ostensive naming; not so for facts.

From a functional perspective one might wonder why a lexical constraint would exist when a general pragmatic bias is available as well. We see three possible advantages to having this domain-specific mechanism. First, all data to date suggest that exclusivity for facts emerges during the preschool years, long after exclusivity for words (Scofield & Behrend, 2007; Markman et al., 2003). This suggests that the pragmatic abilities that underlie contrastive inferences for referential acts in general may develop too late to help word learning get off the ground. For developmental psychologists this may seem counter-intuitive: given the mounting evidence for sophisticated social reasoning in infants, it may seem surprising that toddlers would struggle with what seems like a simple social inference. But this failure is fully consistent with

work on children's ability to calculate pragmatic inferences about the interpretation of linguistic forms. On the pragmatic hypothesis, mutual exclusivity involves the recognition that using the novel form to refer to a previously labeled object would constitute a violation of a pragmatic principle (Clark's principle of contrast or Grice's maxim of manner). There is an extensive body of evidence demonstrating that the ability to make inferences on the basis of violations of Gricean maxims develops gradually over early and middle childhood (see e.g., Noveck, 2001; Papafragou & Musolino, 2003; Huang & Snedeker, in press).

Second, mutual exclusivity as a lexical constraint supports inferences which carry across speakers and conversations. At its simplest, the pragmatic hypothesis does not. On the pragmatic hypothesis, the inference that the speaker will use the same term to refer to the previously labeled object implies that the speaker has used this term for this object in the past and realizes that the listener knows this. This inference should not extend to a new speaker (or perhaps to a conversation taking place at another time). In contrast, mutual exclusivity for words should apply across speakers, since as a lexical principle it makes no reference to speakers or their mental states. Diesendruck and Markson (2001) found that three-year-olds make exclusivity inferences across speakers for words but not for facts. On the face of it, this pattern appears to support the hypothesis that mutual exclusivity for words is subserved by a different mechanism than mutual exclusivity for facts. The authors, however, interpret this data as evidence for children's knowledge of Clark's principle of conventionality, which states that some meanings have conventional forms that speakers in a linguistic community expect each other to use. Is the principle of conventionality a pragmatic constraint or a lexical one? Diesendruck and Markson clearly consider it pragmatic, and Clark (1987) appears to as well, but if the privileged class of

meanings and forms is co-extensive with the lexicon it is not clear that such a distinction can be made.

Finally, having a separate constraint to treat words as mutually exclusive could allow children to adjust the strength of this lexical bias without altering the strength of any commitment they might have about the contrastiveness of other referential acts. The existing evidence suggests that exclusivity for words and facts have very different developmental trajectories. Exclusivity for words is strong from infancy on but becomes more robust with time; exclusivity for facts appears to peak at around four years of age. This could reflect differences in the normative value of each bias at different ages. The factors which influence the contrastiveness of referential acts are potentially different than the factors which influence the degree to which objects labels are mutually exclusive. If the biases arise via separate mechanisms, then, in an adaptive learning system, they could potentially be adjusted independently or conditioned on different information.

Domain-general Hypotheses for Mutual Exclusivity

On the face of it, our findings seem problematic for domain-general accounts of mutual exclusivity. Accounts of this kind attribute mutual exclusivity to general properties of learning systems such as competition between representations during processing and acquisition or a general tendency to prefer simpler hypotheses or one-to-one mappings (Frank, et al., 2009; Regier, 2003). The resilience of mutual exclusivity in children with pragmatic deficits is expected on these theories. However, the discrepancy between exclusivity for facts and words is not. If a bias for one-to-one mappings is simply attributable to a general property of all learning devices, then we should expect this bias to emerge equally in both conditions.

Thus there is clearly one sense in which mutual exclusivity is domain-specific: by middle childhood it applies robustly to words but only weakly (if at all) to facts. But this domain-specific behavior could arise from learning processes that are largely domain-general. There are several ways in which this might transpire.

First, one could envision two parallel systems of mappings, built out the same domain-general pieces, which gradually diverge over development. Perhaps both the mappings from words to their referents and the mappings from facts to objects are achieved by associative networks with an initial bias for one-to-one mappings. If this bias were adaptive, so that it could be strengthened when the data supported it or weakened when it was counterproductive, then the two systems might diverge over time (see Smith et al., 2002 for a similar account of the shape bias). Such an account would be consistent with the developmental trajectory that emerges when we compare the present study with Diesendruck and Markson (2001). Three-year-olds may initially treat facts and words as exclusive, based on a domain-general bias for simple mappings. As children gain more experience with facts, they may learn that most objects are associated with a range of facts both within and across speakers, which could lead them to adjust their bias accordingly. In contrast, while a given object *can* be described by more than one count noun, our strong tendency to repeatedly use the same high frequency basic level terms may ensure that mutual exclusivity remains an adaptive bias for word learning. Developmental change of this kind would be consistent with the domain-general, adaptive accounts offered by Smith (1999; Smith et al., 2002) and Regier (2005).

Second, in domain-general models of mutual exclusivity, the bias arises because word learning is viewed as a mapping process between stable forms at two (or more) levels of representation. If a problem is not represented in this way, it is not clear that an exclusivity bias

would be expected. Facts, unlike simple words, have internal structure. When we interpret a fact we do not simply map the form to a referent or concept, we construct a representation of its meaning though a process of semantic composition. Thus if exclusivity only emerges in systems that learn simple, stable mappings, facts might not be affected.[4]

A closer look at Frank's (2009) model hints at some of the ways in which domain-specific data patterns like ours could arise from a combination of domain-specific levels of representation and a domain-general learning algorithm. Frank models word learning as involving two mappings. First, there is a mapping that is made between objects in a given context and the word tokens that are uttered, mediated by a representation of the speaker's intentions. Second, there is a mapping between word types and object categories which forms the lexicon and is assumed to be stable across situations. In its current instantiation the model is not equipped to handle facts and their meanings (it lacks compositional semantics, treats a word as the unit of reference, and represents the world as consisting solely of objects). However, any version of this model that did represent the referential use of facts would presumably have to do so by mapping tokens of factual descriptions to their referents via the model of the speaker's referential intentions. A pragmatic bias might be captured at that level. It is not clear that these mappings would or should result in lexical entries since the words that compose the facts all have other uses and thus appear when the reference object is absent. In the case of two novel objects, it appears that exclusivity effects in the model would arise solely from a bias for one-to-one *lexical* mappings (see discussion of Xu, 2002 in Frank et al., 2009). If facts do not have lexical entries then no such bias is expected.

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[4] Of course this explanation begs the question of how a child knows the kind of problem that she is confronted with. But since this question is likely to be troublesome for all theories, we put it aside for now.

In sum, the current study was not designed to compare domain-specific lexical accounts with domain-general emergentist accounts, and our findings are consistent with both the possibility of a domain-specific lexical constraint, and with the possibility of a domain-general mechanism that gives rise to a strong bias for mutual exclusivity in words but not in facts.

Conclusions

Our results demonstrate that high-functioning children with ASD can use mutual exclusivity to infer that a novel word refers to an object that has not been named. This extends the findings of Preissler and Carey (2005) by showing that children with ASD are not merely matching novelty-to-novelty but actually interpreting words as referring to mutually exclusive categories of objects. Furthermore, we found that exclusivity for words was more robust in several respects than exclusivity for facts, both in typically developing children and in children with ASD. Mutual exclusivity for words was associated with vocabulary size while mutual exclusivity for facts was associated with social pragmatic skills. These results suggest that different mechanisms account for children's tendencies to treat words and facts contrastively, and are inconsistent with the pragmatic hypothesis, which is based on the premise that a single factor underlies both tendencies. These results are consistent with domain-specific theories in which mutual exclusivity is a lexical constraint and also with theories in which domain-general mechanisms give rise to domain-specific patterns of interpretation.

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Table 1

Demographic and Symptom Severity Variables by Diagnostic and Age Group

	ASD kids *M* (*SD*) Range	TD kids *M* (*SD*) Range	ASD teens *M* (*SD*) Range	TD teens *M* (SD) Range
N	26	24	16	16
Gender (M:F)	22 : 4	14 : 10	14 : 2	14 : 2
CA[a] (years)	8.1 (2.3)	7.6 (2.2)	15.1 (1.2)	14.9 (1.3)
	4.2 – 11.8	4.9 – 11.9	13.1 – 16.9	12.8 – 17.6
PPVT (standard score)	112 (19)	118 (12)	113 (12)	119 (8)
	87 – 148	86 – 139	92 – 135	105 – 137
SCQ				
Total	20 (5)	3 (2)	21 (7)	2 (3)
	13 – 31	0 – 8	10 – 29	0 – 9
RSI[b]	6 (3)	0 (1)	8 (4)	0 (1)
	1 – 12	0 – 2	2 – 13	0 – 2

Communication	7 (2)	2 (1)	6 (3)	1 (2)
	1 – 10	0 – 4	2 – 9	0 – 7
RBI[c]	6 (2)	1 (1)	6 (2)	0 (1)
	1 – 8	0 – 3	1 – 8	0 – 2

Note: Fifteen is the threshold on the SCQ for autism spectrum disorders; higher scores indicate greater severity. There were 7 children in the ASD group who were below threshold on this parent-report questionnaire. Diagnoses for these participants relied on the existence of pre-existing diagnosis by an experienced professional.

[a] CA = Chronological age

[b] RSI = Reciprocal social interaction

[c] RBI = Repetitive behaviors and interests

Table 2

Proportion of Responses Treated as Mutually Exclusive, by Order, Group, and Condition.

		Tested first	Tested second	Improvement[a]	*t* (df)	*p*
ASD						
	Label *M* (*SD*)	90% (15)	81% (19)	- 9%	1.85 (40)	.07
	Fact *M* (*SD*)	61% (32)	74% (27)	+ 13%	1.40 (40)	.17
TD						
	Label *M* (*SD*)	85% (24)	89% (24)	+ 4%	-0.50 (38)	.62
	Fact *M* (*SD*)	60% (22)	89% (22)	+ 29%	4.12 (38)	<.001

Note. Values in the *Tested first* column represent the percent of unlabeled object choices for the first condition administered. Values in the *Tested second* column represent performance on the second condition administered. *Improvement* values reflect the mean difference between participants who received the given condition first and those who received the condition second. *T*-tests were performed to test this mean difference.

Figure Captions

*Figure 1.*Percentage of trials on which participants treated labels and facts as mutually exclusive, by diagnostic group. Chance performance for both conditions is 50%; *t*-tests against chance performance for all four cells were reliable ($p < .001$).

Figure 2. Comparison of control task and exclusivity task for participants who received both. For the control task the correct referent is the labeled object, for the exclusivity task the correct referent is the unlabeled object.

Figure 1.

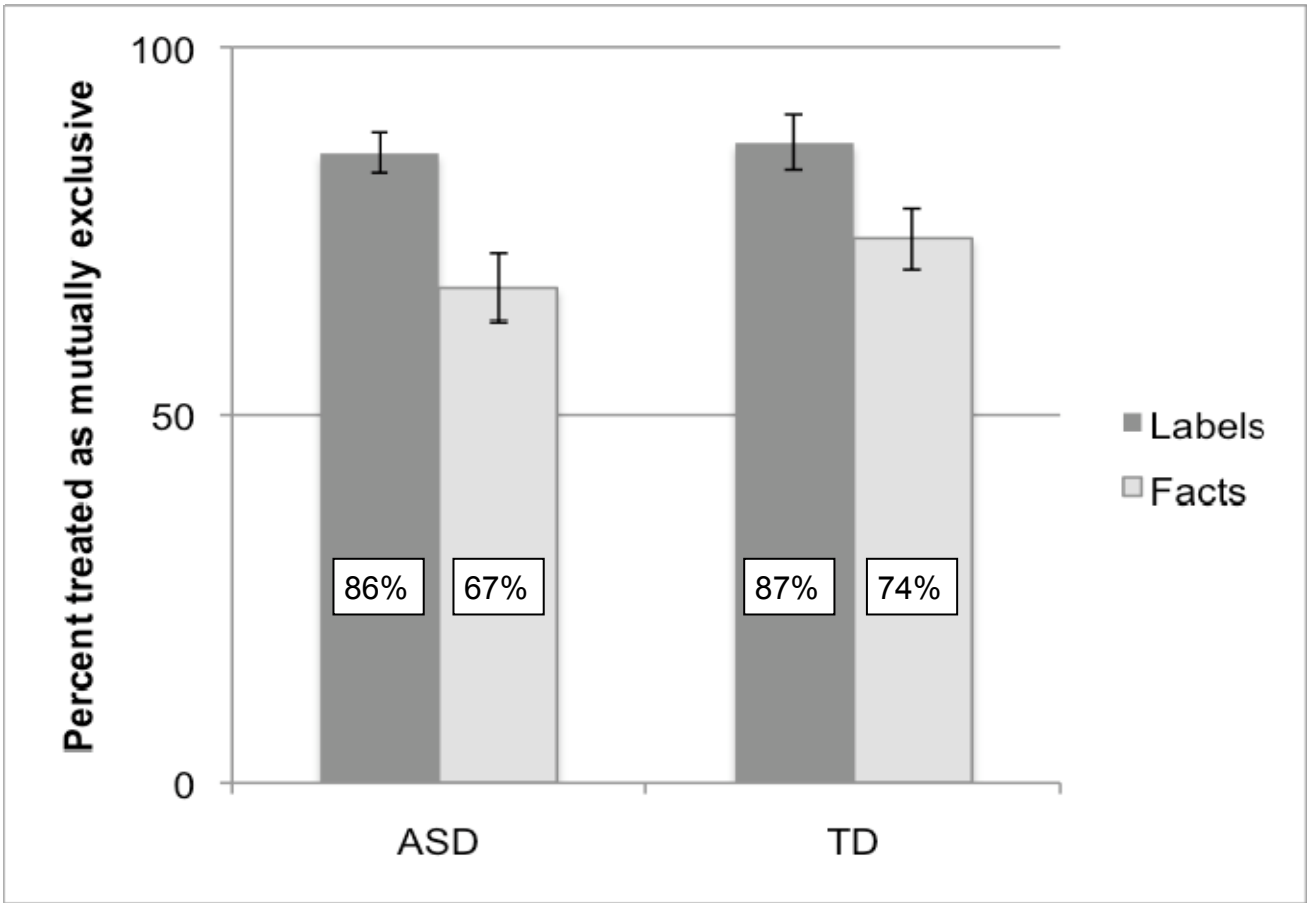
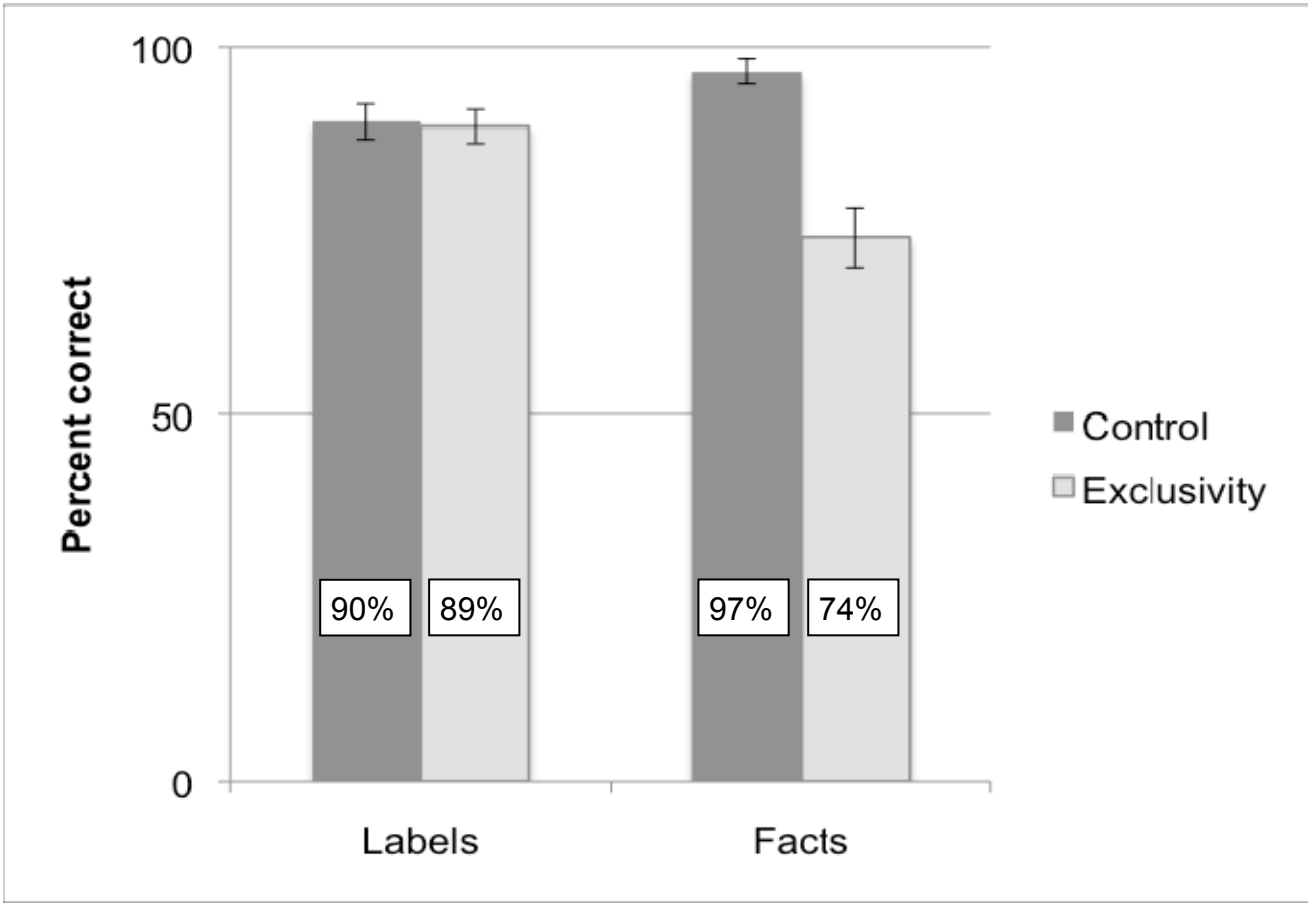

Percent treated as mutually exclusive
100
50
0
86%
67%
87%
74%
ASD
TD
Labels
Facts

Figure 2.


100
50
0
Percent correct
90%
89%
97%
74%
Labels
Facts
Control
Exclusivity